



Jet Propulsion Laboratory  
California Institute of  
Technology

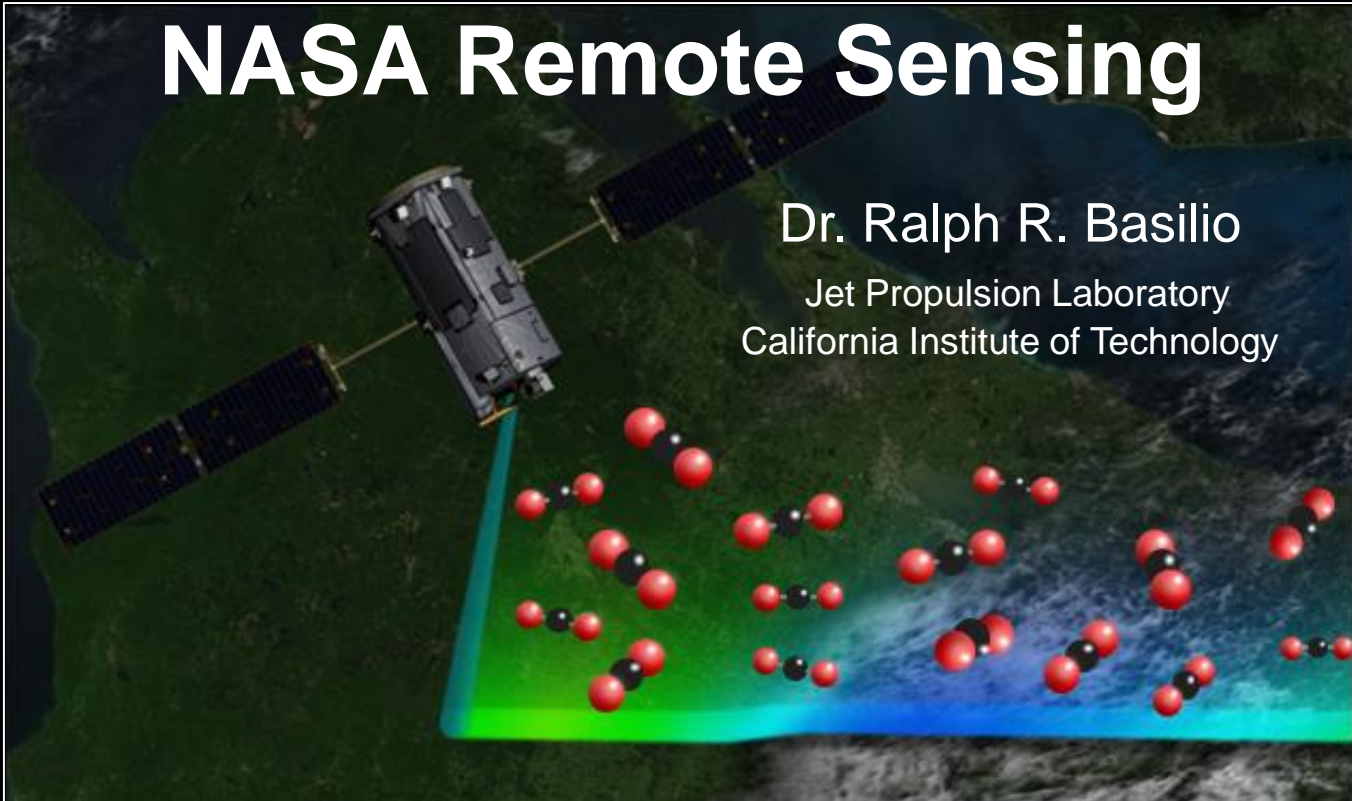
# Earth and Environmental Engineering Colloquium – Fall 2017 The Fu Foundation School of Engineering and Applied Sciences (SEAS) Columbia University in the City of New York

Thursday, 02 November 2017, 11:40 am – 12:55 pm ET, 702 Hamilton Hall

## NASA Remote Sensing

Dr. Ralph R. Basilio  
Jet Propulsion Laboratory  
California Institute of Technology

Credit: NASA Jet Propulsion Laboratory



Reference: Clearance No. CL#17-xxxx

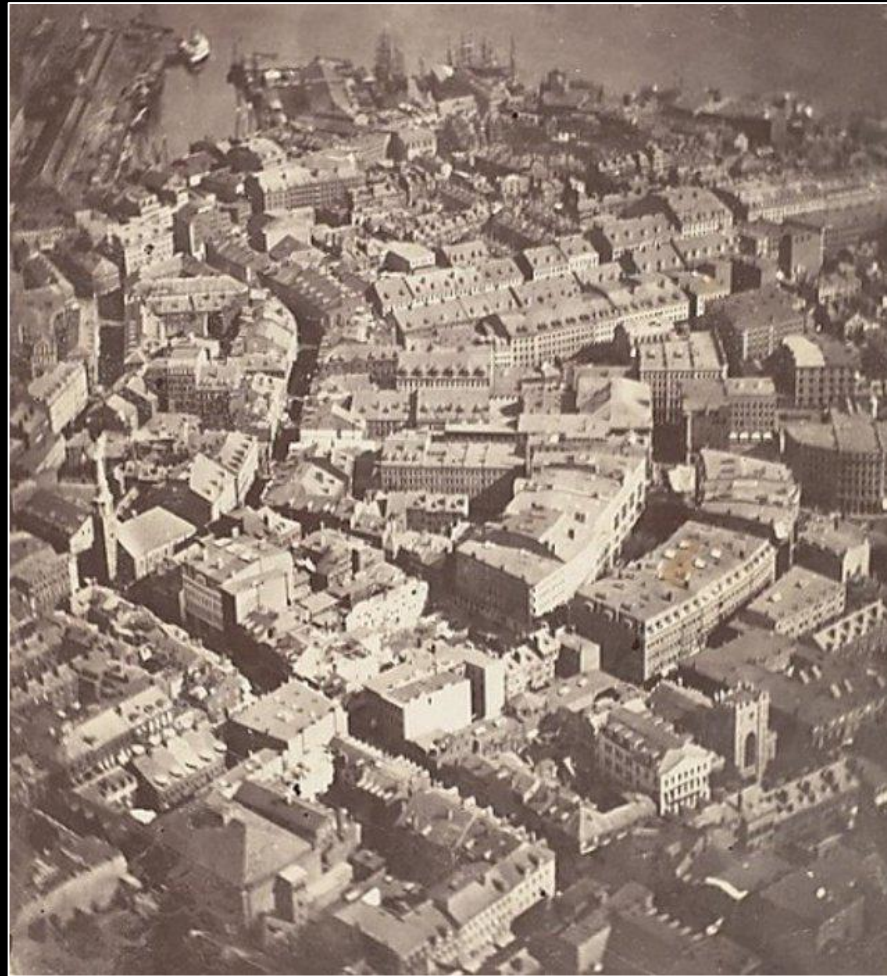


*The term "remote sensing," first used in the United States in the 1950s by Ms. Evelyn Pruitt of the U.S. Office of Naval Research, is now commonly used to describe the science—and art—of identifying, observing, and measuring an object without coming into direct contact with it.*

*- NASA Earth Observatory*



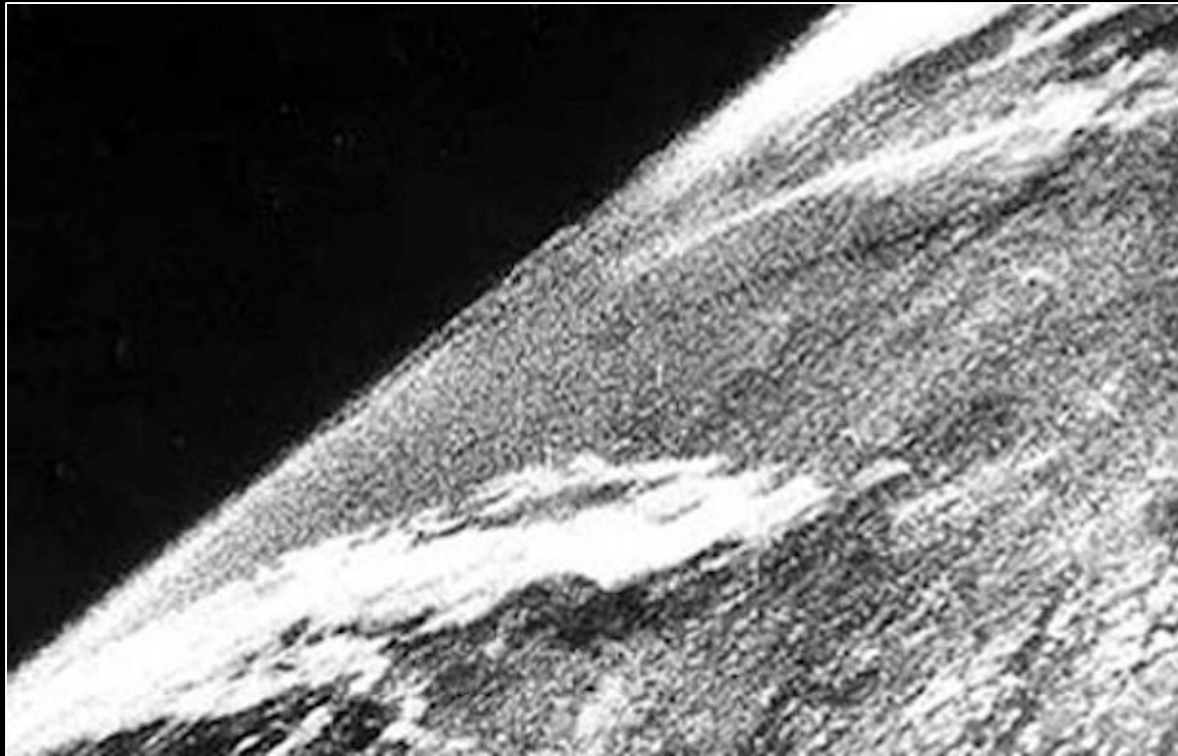
# *"Boston, as the Eagle and Wild Goose See It"*



*Credit: James Wallace Black, 1860*



## *First Photograph of the Earth from Space*



*Credit: White Sands Missile Range/Applied Physics Laboratory, 24 October 1946*



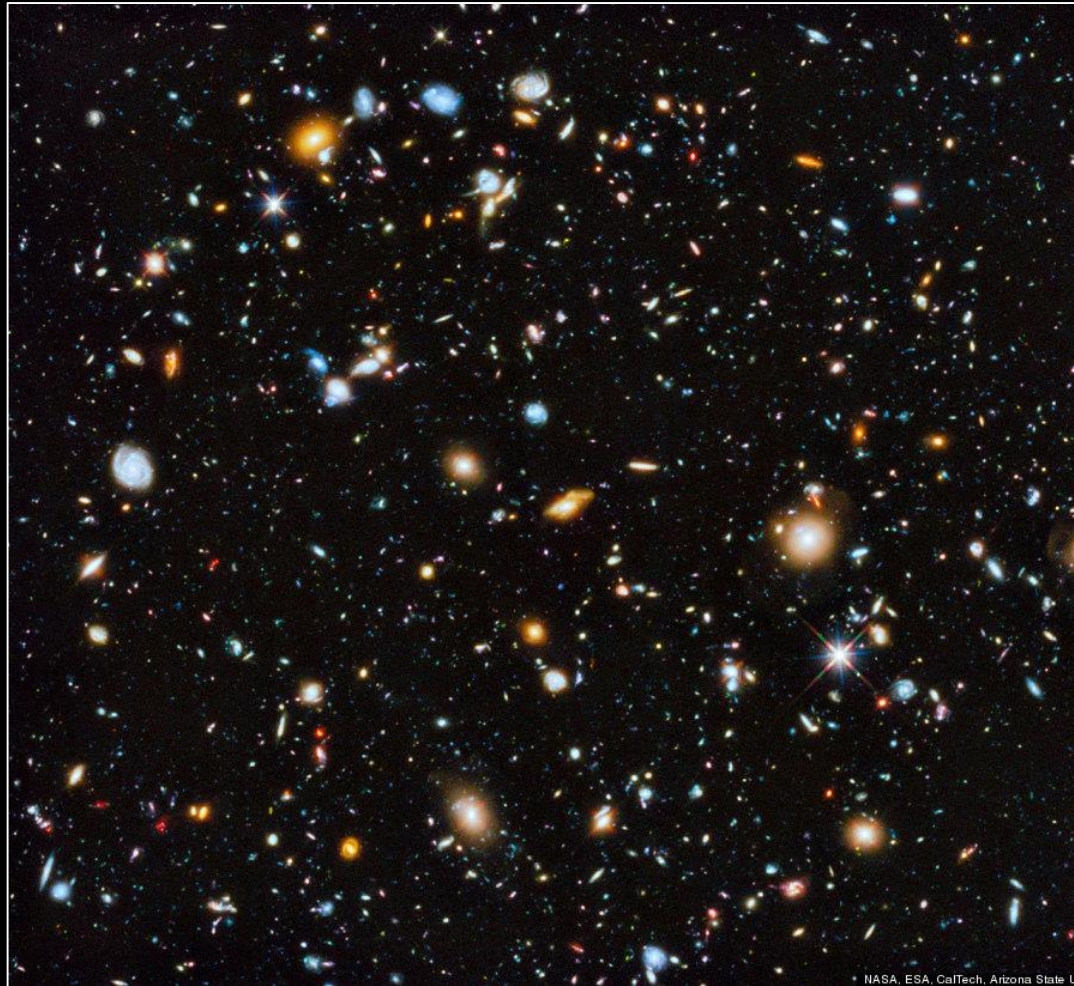
## *First Photograph of the Earth from the Moon*



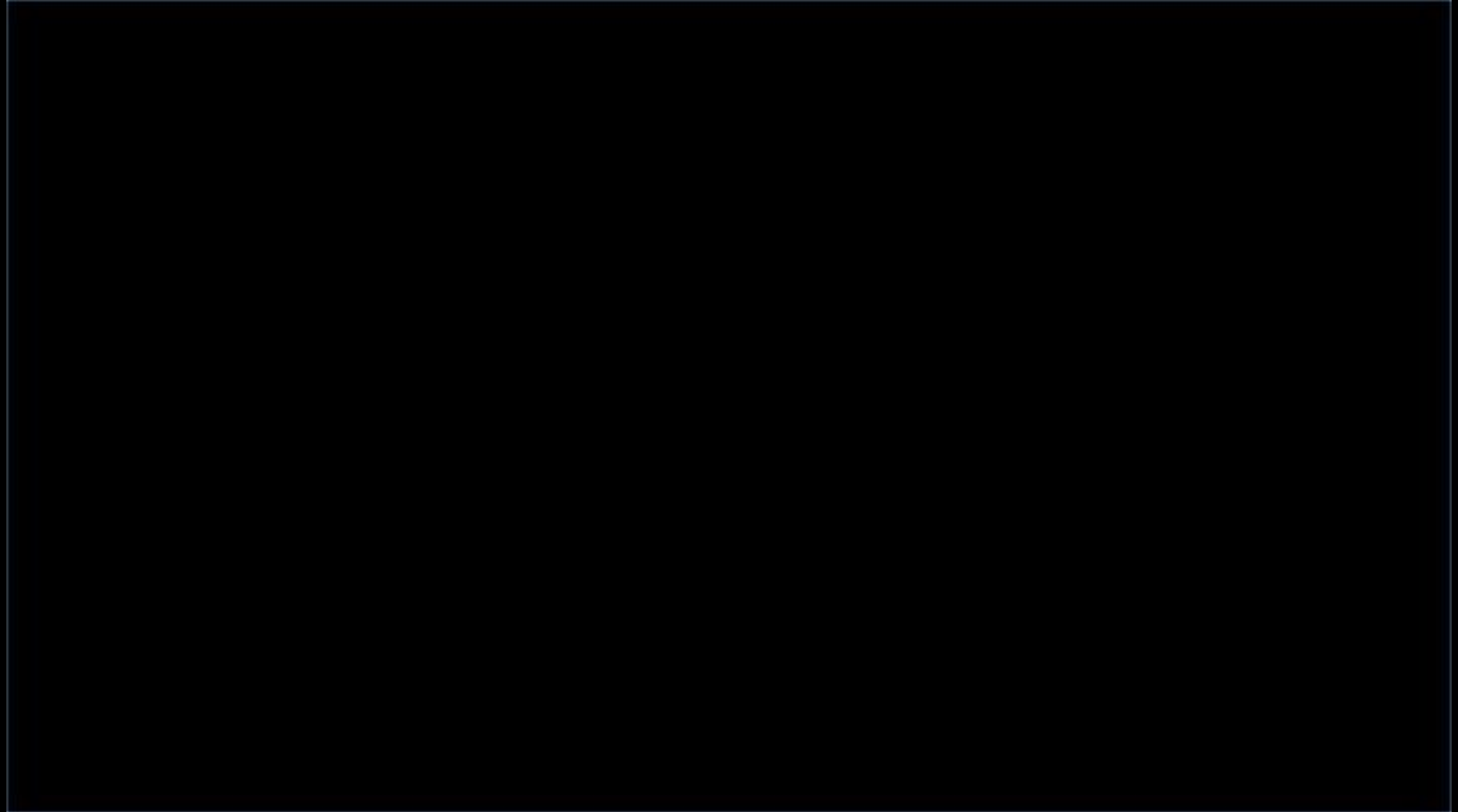
*Credit: NASA, Lunar Orbiter, 23 August 1966*



# *Hubble Space Telescope (HST) Ultra Deep Field Image*



Credit: NASA, ESA, and G. Bacon (STScI), 2014



*Credit: NASA, ESA, and G. Bacon (STScI), 2014*



*The James Webb Space Telescope (JWST), to launch in 2019, will see further back in time than any other any other observatory before*



Credit: NASA, May 2017



*Until recently NASA spaceflight missions have generally  
served a singular need*

*...that of science/research*



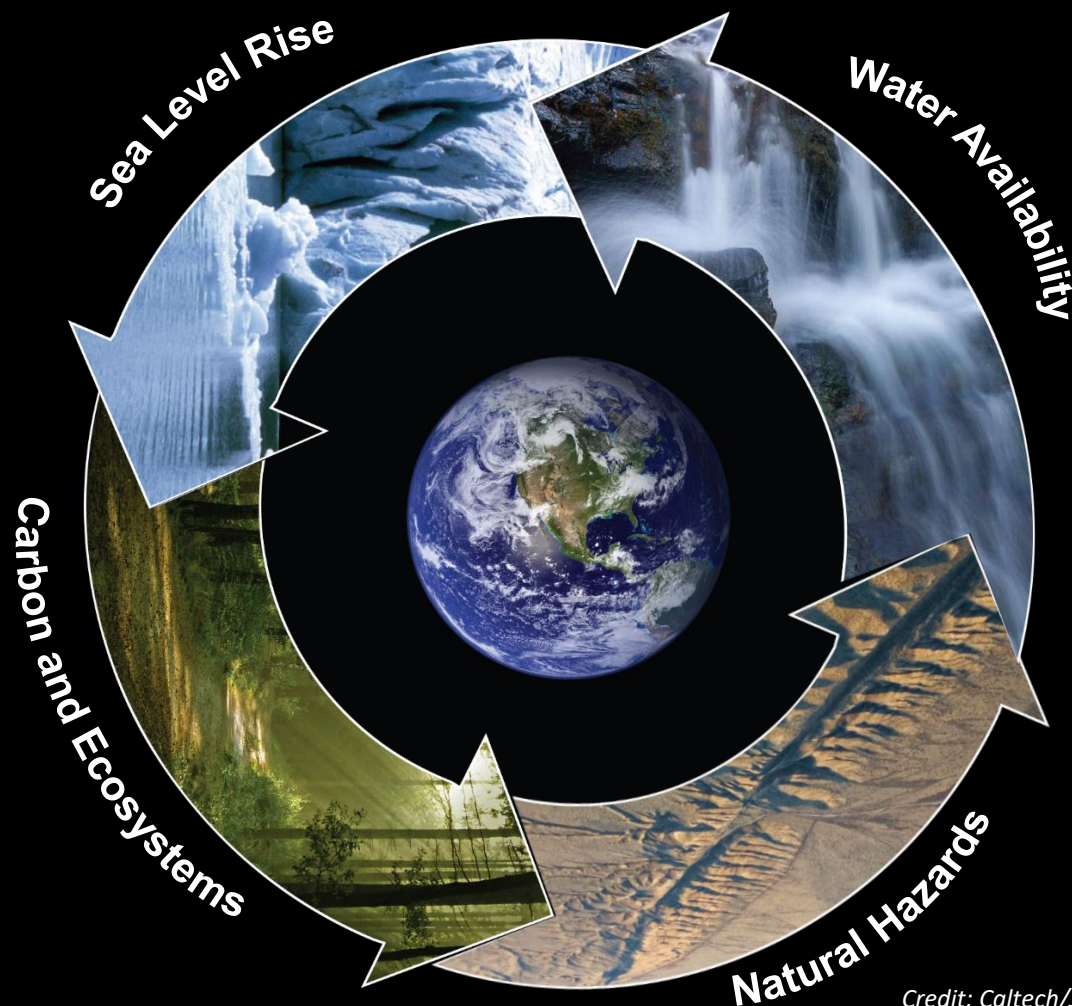
*However,*

*...The times are a changin'*

*- Title of song by Bob Dylan,  
2016 Nobel Prize for Literature*

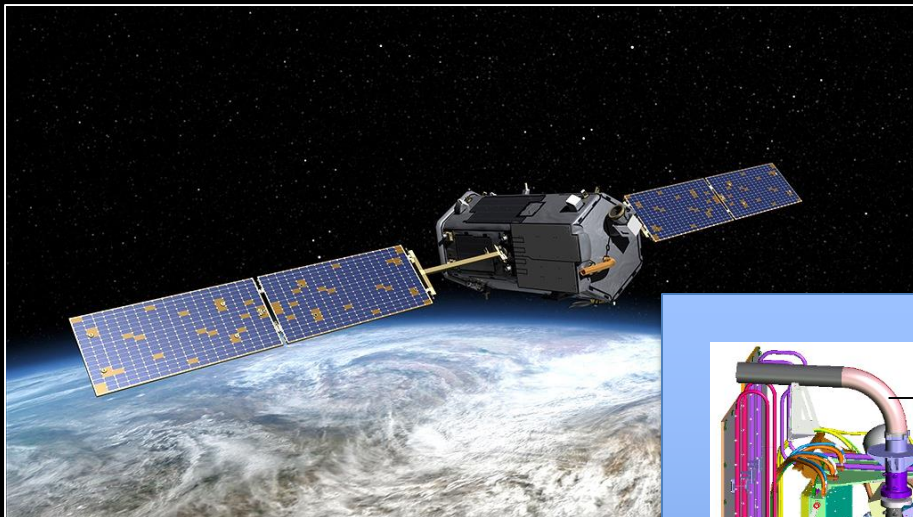


## *A Concerted Effort at JPL*



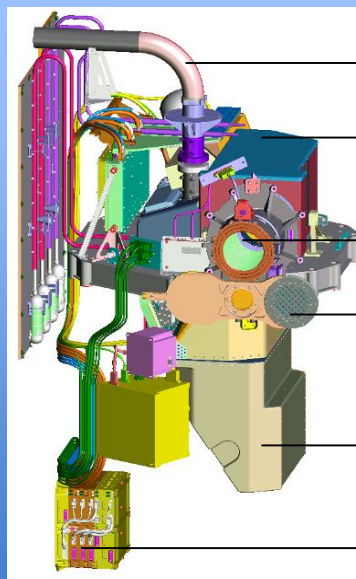
Combining system engineering expertise with advanced technologies and science expertise to provide reliable and accurate information (e.g., science data applications)

*Credit: Caltech/Jet Propulsion Laboratory*



*Credit: Caltech/Jet Propulsion Laboratory*

## Orbiting Carbon Observatory-2 (OCO-2)



Vent Pipe

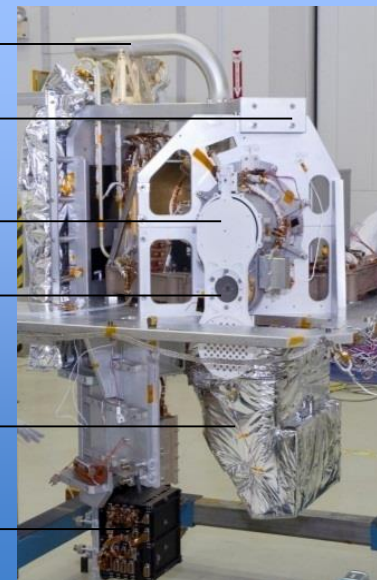
Primary Instrument  
Assembly (PIA)

Telescope Opening

Baffle/Calibration  
Assembly (BCA)

Optical Bench  
Assembly (OBA)

Remote Electronics  
Module (REM)

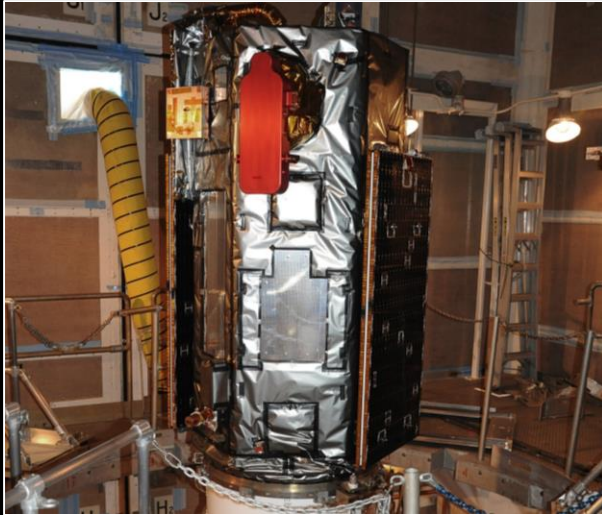


*(Basilio, Pollock, Hunyadi-Lay, 2014)*

*Credit: NASA/Jet Propulsion Laboratory*



## 02 July 2014 Launch



*Credit: NASA/Jet Propulsion Laboratory*



*Credit: NASA*



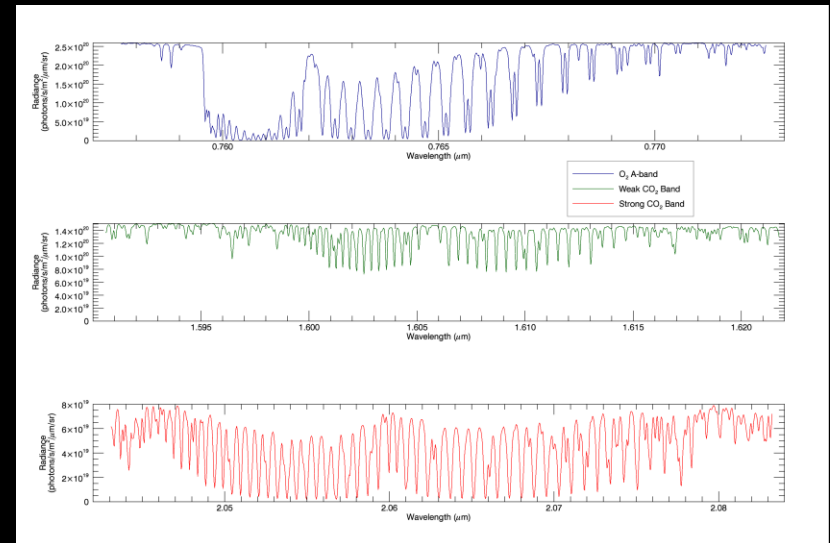
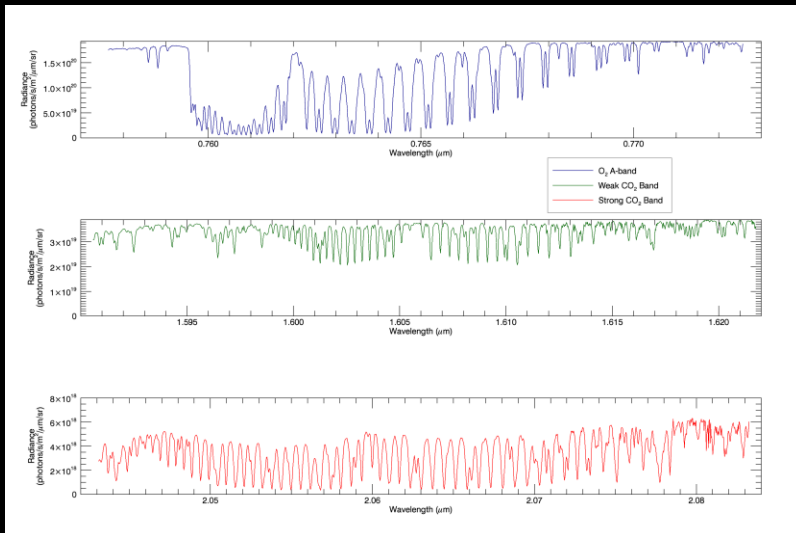
*Credit: Orbital Sciences Corporation*



*Credit: NASA*



## Beautiful 'First Light' Spectra



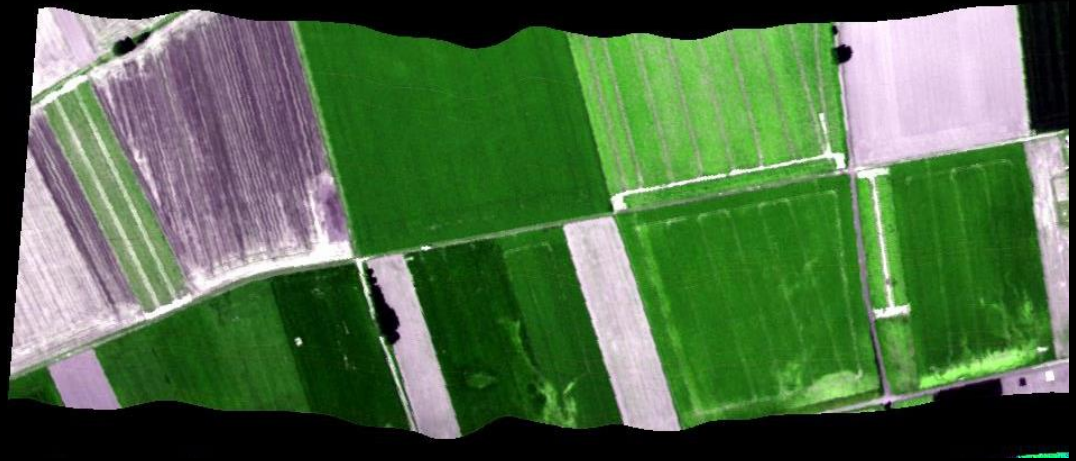
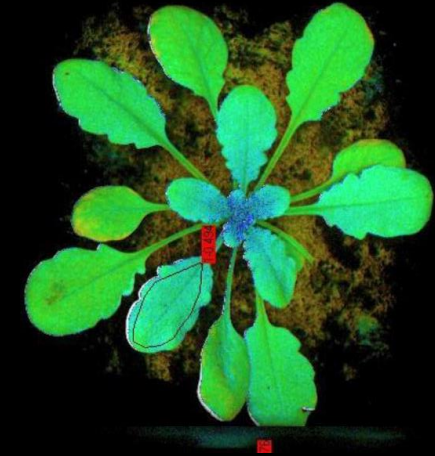
**From Ground Test (April 2012)**

**In-Flight Data (06 August 2014)**

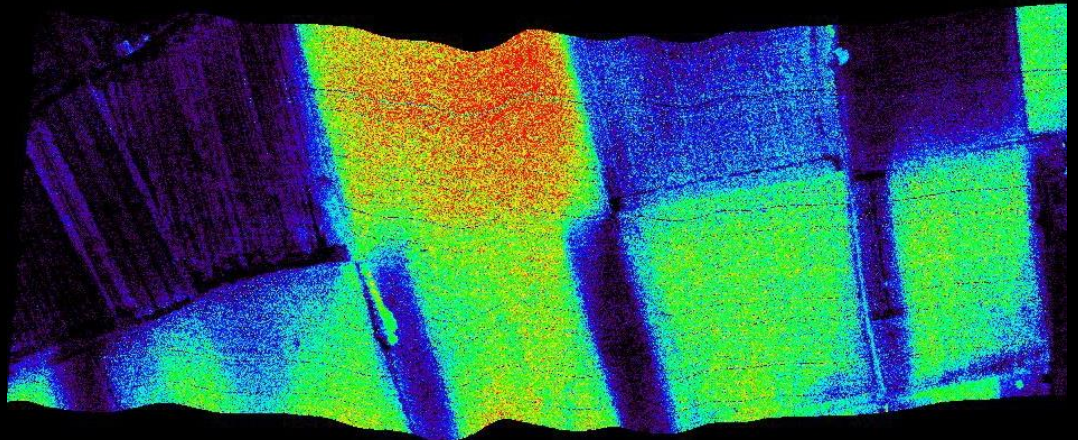
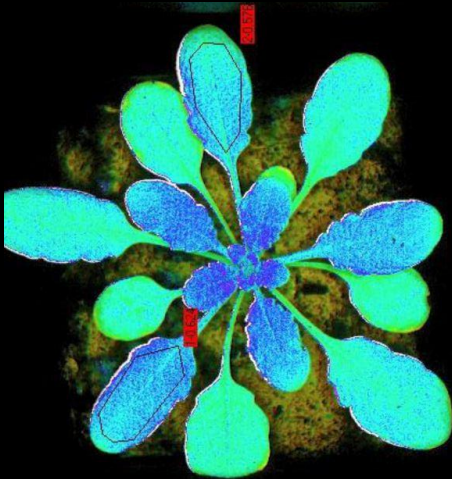
*(Basilio, Pollock, Hunyadi-Lay, 2014)*

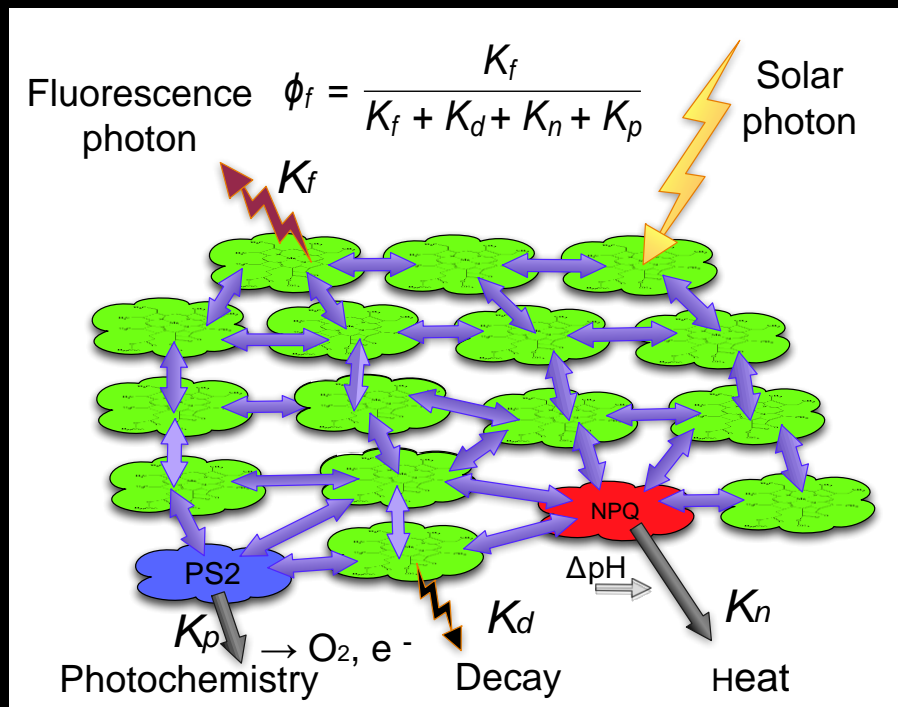


# Plants Grow and Plants Glow



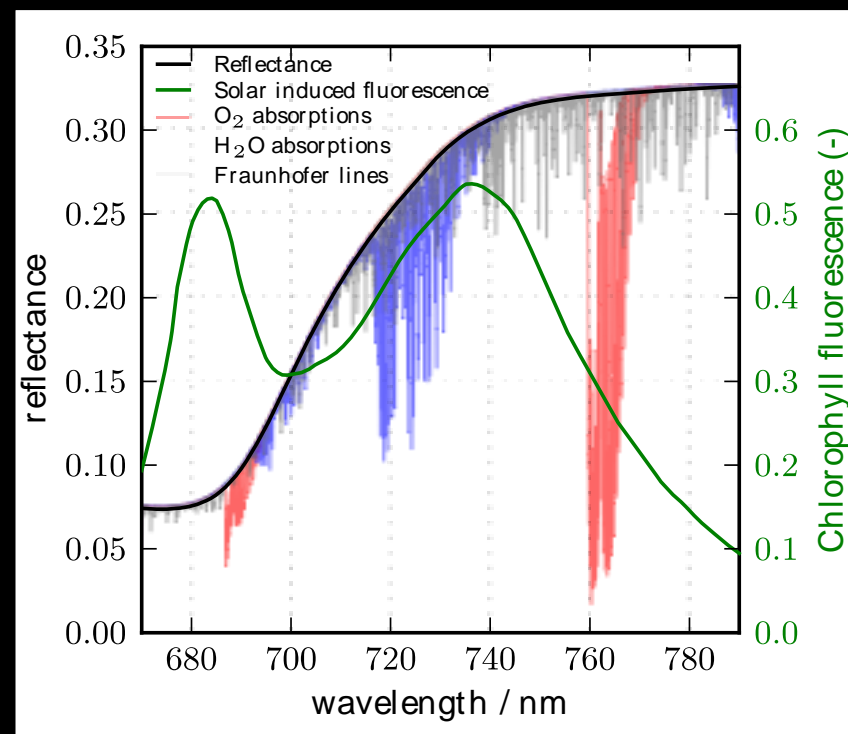
Credit: ESA / U. Rascher, Forschungszentrum Jülich





(Frankenberg et al., 2013)

## Solar-Induced chlorophyll Fluorescence (SIF)



(Frankenberg, 2013)



# Science Data Application: Contribution to Agricultural Research



- *Terrestrial Gross Primary Production (GPP) is the largest global carbon flux*
- *Ground-based GPP compared with space-based SIF*
- *Linear GPP-SIF relationships were found that were robust in both space and time*
- *GPP derived from SIF found to be a better regional-scale estimator than that obtained through tall towers alone or other space-based measurements*

(Wood et al., 2016)



# Western States Water Mission (WSWM)

Jet Propulsion Laboratory, California Institute of Technology

## The Western States Water Mission



CUAHSI Hydroinformatics meeting  
16 July 2015



(Reager, CUASI presentation, 2015)

## THE JET PROPULSION LABORATORY (JPL) WESTERN STATES WATER MISSION (WSWM)

A Prototype for a Hyper-Resolution  
Hydrological Modeling and Data Analytics &  
Visualization Platform

James S. Famiglietti, Ralph R. Basilio, Daniel J. Crichton, Cedric H. David, Thomas G. Farr, Stephanie L. Granger, Jonathan M. Hobbs, Steven R. LeVoe, Shan Malhotra, Catalina Qaida, Gregory B. Osterman, John T. Reager, Michael Bueckert, Dimitrios Stampanoulis, Amy R. Tangsud, Michael J. Turrono

The Jet Propulsion Laboratory, California Institute of Technology has developed a working prototype of a hydrological and data science web-based tool that will serve the needs of science/research, data applications, and informed decision-making.

**INTRODUCTION.** Water makes up 50% to 75% of the human body weight. It is an excellent solvent that allows for the transportation of nutrients and waste, it serves as a lubricant for proper food digestion and joint mobility, and it serves to regulate our body temperature through perspiration and

evaporation. In fact, water is the essence of life on Earth. Without it there would be no animals, plants, and simple life forms. Every living thing requires dependable, clean water to thrive. There will be greater demands as the human population continues to grow: the 8 billion mark will be reached by the middle of the next decade with an ever-increasing growth rate predicted beyond. However, the urgency in better estimating current and future amounts is already being felt close to home, namely the state in which we live. California recently faced one of the most severe droughts in the state's recorded history: given relatively low rainfall amounts and unquenchable thirst for domestic, industrial, agriculture, and environment use, reservoir levels dropped to unprecedentedly low levels. Meanwhile, groundwater in aquifers, the strategic water supply reserve during periods of prolonged drought, continues to be depleted at unsustainable rates. While voluntary, and in increasingly more regions, mandatory water conservation measures have been

**AFFILIATIONS:** Famiglietti, Basilio, Crichton, David, Farr, Granger, Hobbs, LeVoe, Malhotra, Qaida, Osterman, Reager, Bueckert, Tangsud, and Turrono - Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; Stampanoulis - University of California, Los Angeles.

**CORRESPONDING AUTHOR:** James S. Famiglietti, [James.S.Famiglietti@jpl.nasa.gov](mailto:James.S.Famiglietti@jpl.nasa.gov)

The abstract for this article can be found in this issue, following the table of contents.

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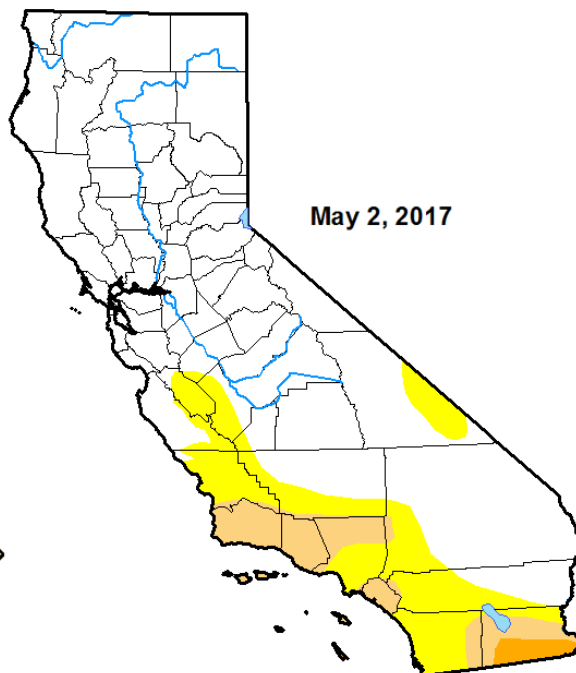
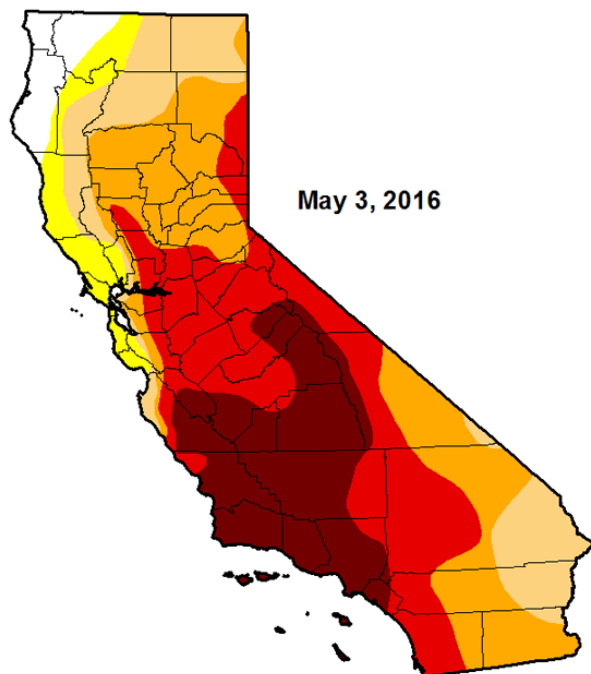
[Publication Name, Date, and Page Number]

(Famiglietti et al., pre-publication 2017)



# Water is Always of Interest in the West!

## U.S. Drought Monitor California



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	76.47	23.53	8.24	1.06	0.00	0.00
Last Week 04-25-2017	76.54	23.46	8.24	1.06	0.00	0.00
3 Months Ago 01-31-2017	38.98	61.02	50.80	20.30	1.87	0.00
Start of Calendar Year 01-03-2017	18.07	81.93	67.61	54.02	38.17	18.31
Start of Water Year 09-27-2016	0.00	100.00	83.59	62.27	42.80	21.04
One Year Ago 05-03-2016	4.27	95.73	89.68	74.37	49.15	21.04

### Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions.  
Local conditions may vary. See accompanying text summary  
for forecast statements.

### Author:

Brian Fuchs  
National Drought Mitigation Center



<http://droughtmonitor.unl.edu/>

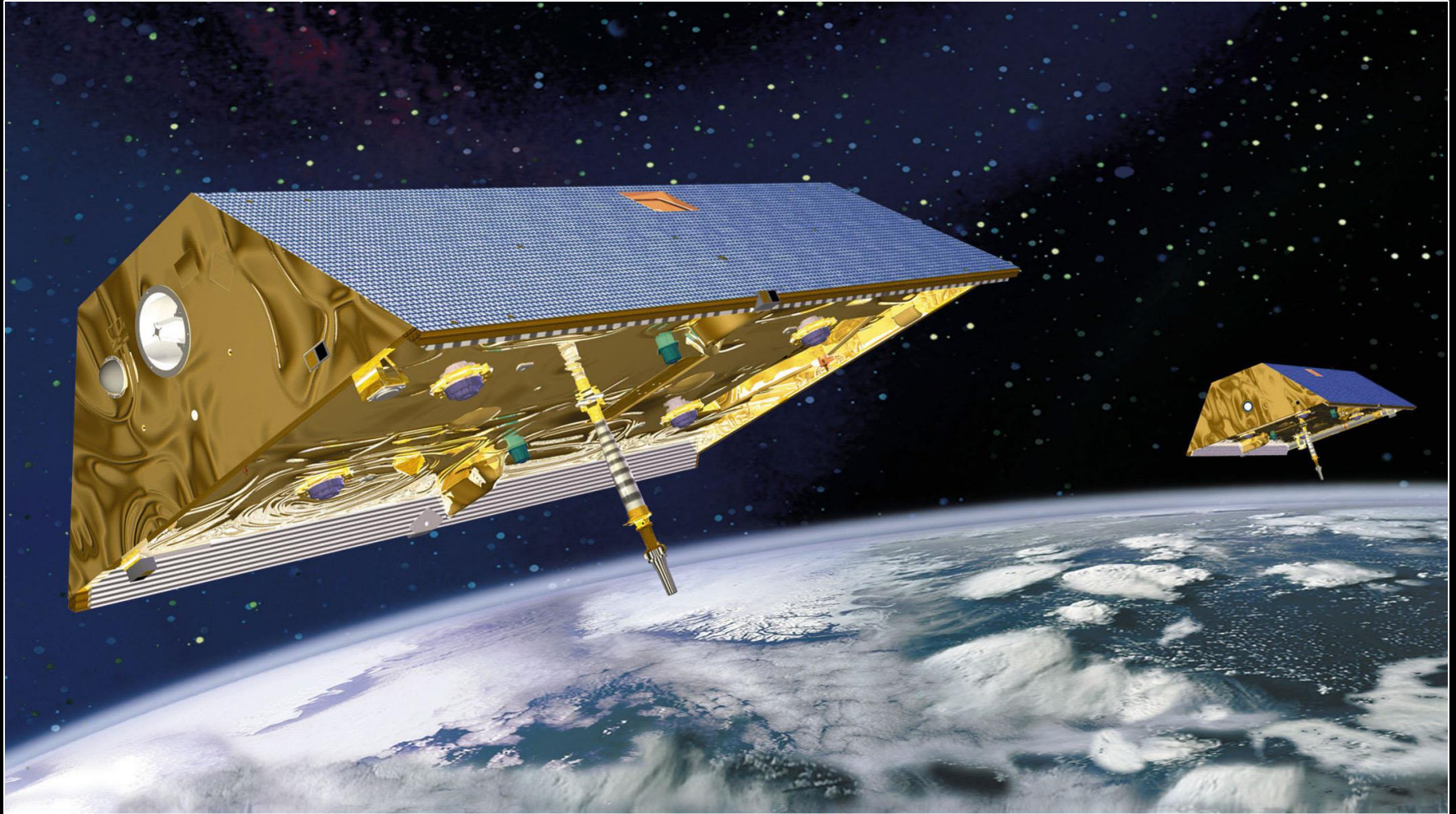


## System Highlights

- *Flight project approach to development and validation*
- *Input of space-based, airborne, and in situ sensor data*
- *Use of land surface models*
- *Multi-sensor data assimilation*
- *High (hyper-scale) spatial resolution*
- *Down-scaled estimates of groundwater*
- *Uncertainty quantification*
- *Data science (scalability, analytics, and visualization)*



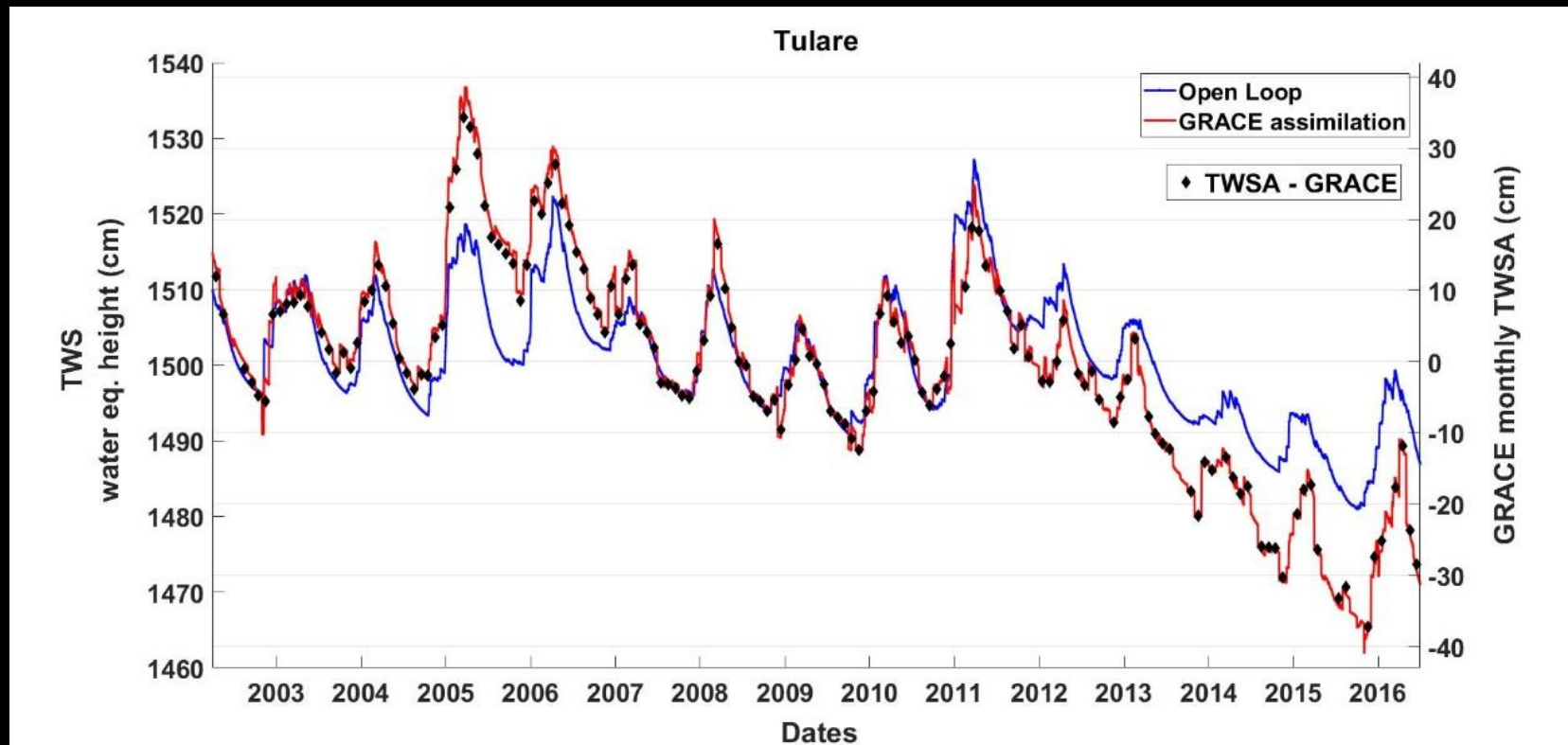
## *Twin GRACE Spacecraft*



*Credit: NASA/Caltech-Jet Propulsion Laboratory*



## *Data Assimilation Improves the Estimates of Total Water Storage (TWS)*



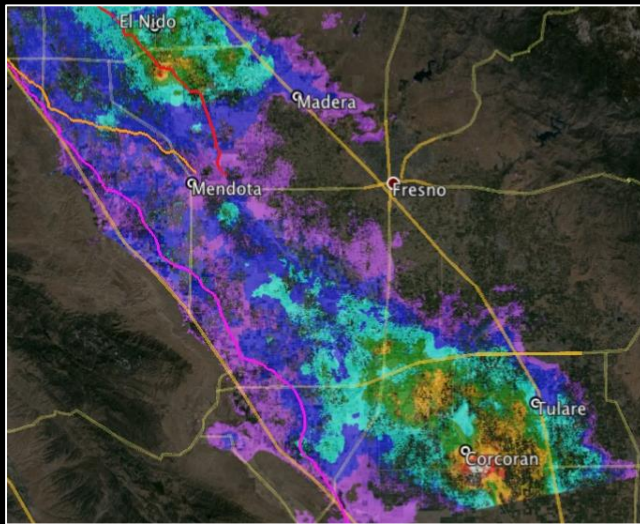
*(Stampoulis et al., pre-publication 2017)*



## Science/Research:

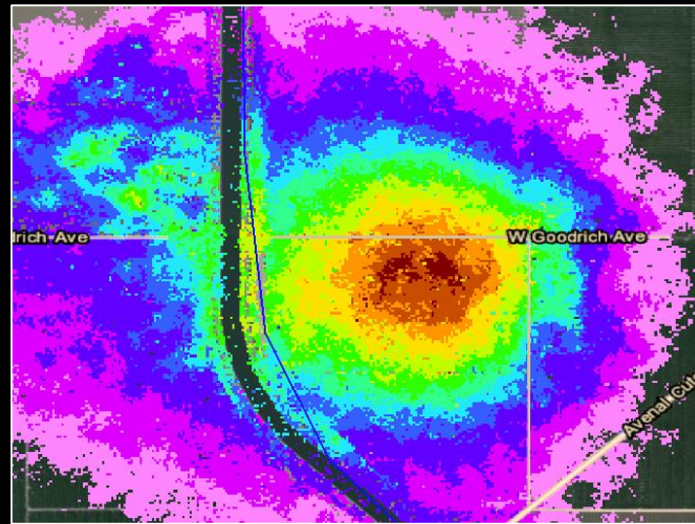
# NASA Research on Land Subsidence Due to Pumping of Groundwater

CA Central Valley



Credits: Canadian Space Agency/NASA/JPL-Caltech

CA Aquaduct Near Huron



Credits: Canadian Space Agency/NASA/JPL-Caltech

- How does subsidence correlate with estimates of groundwater availability and well depth measurements?
- What level of rebound was observed during the 2016-2017 water year?



*Potential Science Data Application:  
Augmenting the data-information found in the State of  
California Groundwater Information Center (GIC)*



*Credit: State of California Department of Water Resources (DWR)*



*Potential for [Better] Informed Decision-Making:  
What stage of water conservation measures should be  
employed this water year?*

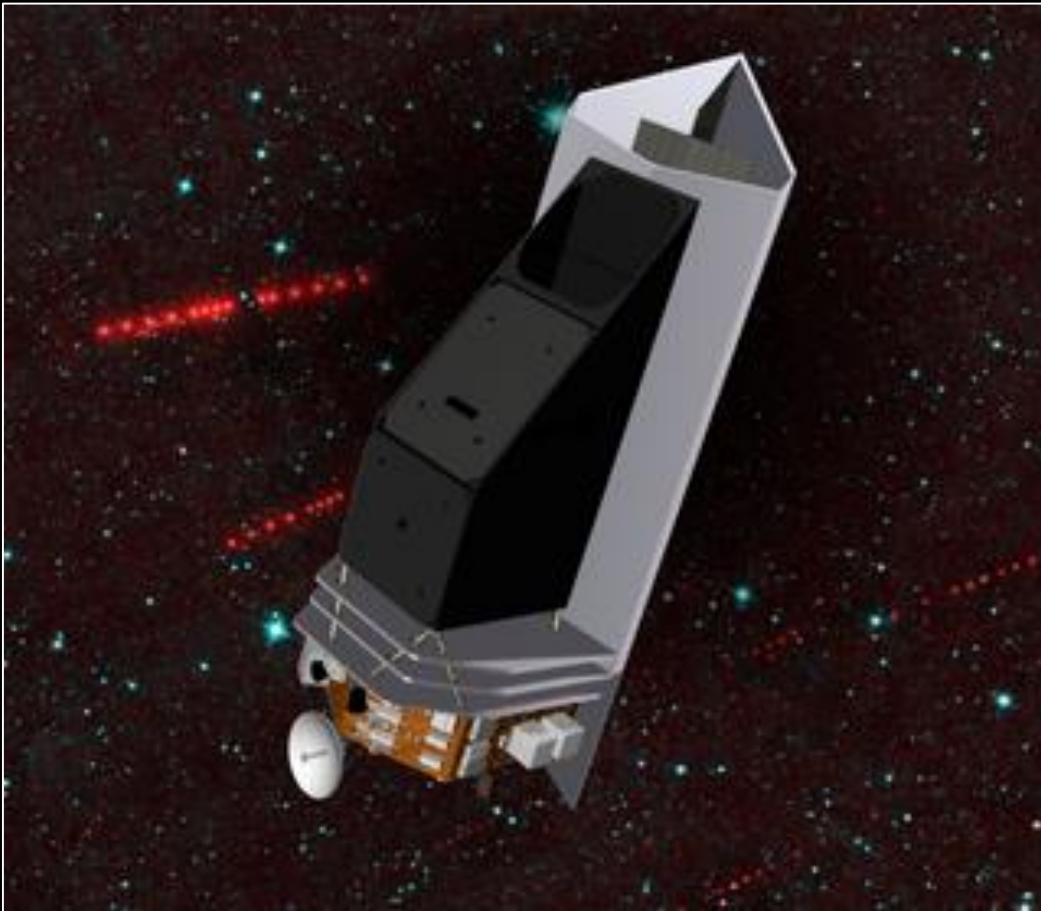


Credit: Metropolitan Water District of Southern California, 2010



# *Near-Earth Object Camera (NEOCam)*

*[Proposed Mission]*



- ✓ *Science Data Application*
- ✓ *Science/Research*
- ✓ *Informed Decision-Making*

*Credit: NASA/Caltech – Jet Propulsion Laboratory*



*We must seek to maximize the rate of return  
on investments by serving the needs of  
science/research, data applications, and  
informed decision-making*

*- Ralph R. Basilio*

*Presentation to the National Academies*

*Board on Earth Sciences and Resources (BESR), 09 May 2017*



*Thank you to:*

*Dr. Pierre Gentine,  
Department of Earth and Environmental Engineering,  
Columbia School of Engineering and Applied Sciences (SEAS),  
faculty, researchers, graduate students, and other attendees*

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Office: 818.354.3228*

\* NASA, ESA, CalTech, Arizona State U.